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THESIS

A COST-PERFORMANCE ANALYSIS
OF COMPUTER ALTERNATIVES

by

Gladys Twining Connolly

December, 1982

Thesis Advisor: Carl R. Jones

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A Cost-Performance Analysis of Computer Alternatives

by

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B.A., University of Colorado, 1977

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TABLE OF CONTENTS

I. INTRODUCTION 8
A. BACKGROUND ON SMALL BUSINESS COMPUTERS 8
B. COMPUTERS IN TRANSIT MANAGEMENT 9
C. PROBLEM DEFINITION AND OBJECTIVE 12
D. SOURCES 14

II. MONTEREY-SALINAS TRANSIT ORGANIZATION AND REQUIREMENTS 15
A. ORGANIZATION OF MST 15
B. REQUIREMENTS ANALYSIS 17
1. Current System 17
2. Indicators of System Size 25
3. Application Areas 28

III. PRESENTATION OF ALTERNATIVES 32
A. GENERAL 32
B. LOCAL AREA NETWORKS 32
C. THE COMPUTER SYSTEMS 35
1. The Minicomputers 35
2. The Microcomputers 38
D. ASSUMPTIONS 42

IV. ANALYSIS AND CONCLUSIONS 44
A. ANALYSIS OF ALTERNATIVES 44
B. ADDITIONAL FACTORS 57
C. CONCLUSIONS 60

APPENDIX A: MONTEREY-SALINAS TRANSIT'S FILES AND REPORTS 61

LIST OF REFERENCES 65

INITIAL DISTRIBUTION LIST 67

LIST OF TABLES

I. Trans-Pac Hardware and Software 36
II. Wang Hardware and Software 37
III. Intertec CompuStar Hardware and Software 39
IV. Nestar Cluster/One Network Hardware and Software . 41
V. Software Performance Scores 47
VI. Software Performance Variability A 52
VII. Software Performance Variability B 53
VIII. Software Performance Variability C 54
IX. Personnel and Payroll Files 61
X. Maintenance Files and Reports 62
XI. Financial Files 63
XII. Service Planning and Scheduling Files 63
XIII. Reports and Efficiency Measures 64

LIST OF FIGURES

4.1 System Performance vs. System Cost 48

4.2 System Performance vs. System Cost Ranges . . . 49

4.3 Performance Ranges vs. System Cost Ranges . . . 55

I. INTRODUCTION

A. BACKGROUND ON SMALL BUSINESS COMPUTERS

What was once the province of Fortune 500 companies has become a topic of interest everywhere from boardrooms to stockrooms, steel mills to Mom and Pop groceries. Computers are no longer reserved for companies with high-budget data processing (dp) departments and ranks of programmers at the ready. Technological advance over the last two decades has allowed the "cost per computation" to plummet so that computer power is available to anyone with a few hundred dollars to spend. To exploit this steadily growing market of hardware owners, software producers have rushed to supply ready-made software: "horizontal" packages which apply to nearly every business--payroll, inventory control and general ledger, for example; and "vertical" applications which are directed toward a single industry--job-costing for a building contractor, for example [1:36]. The advent of small and inexpensive computers, coupled with a dazzling array of prepackaged software and the ever-increasing costs of labor, has made the computer as ordinary an instrument of business as the telephone.

But for a company with slightly unique needs, locating appropriate vendors is in itself a major chore. The average business user is apt to be overwhelmed by the number of salesmen anxious to lay claim to his dp dollar, whether or not they can effectively meet his needs. With the multitude of sources for obtaining a system--turnkey operations, direct manufacturer sales, computer retailers--and the range of implementations--traditional minicomputer, microcomputers, networks, distributed processing--a buyer must be aware of the whole spectrum of options.

Making a choice was definitely simpler when alternatives could be placed into rigidly delineated categories. In the not-too-distant past, a minicomputer was the choice for a small businessman, a microcomputer for the hobbyist. Today, one estimate places 60% of all micros sold into small businesses and professional offices [2:79]. Data Sources, a quarterly guide to equipment, software services and companies in the information processing industry, groups its less-than-mainframe sized computer systems into high-end, mid-range, and low-end minicomputers, microcomputers, and small business computers, ranged by price in each division. A quick scan shows that price is not a dependable indicator of classification: both low-end minis and microcomputers list systems under $15,000; a great number overlap in the $30,000 to $75,000 range; and one micro system spills into the "greater than $350,000" range. Once an organization has determined what general size and price classification it fits into, it must locate software which is responsive to its needs. If the small business in question is in the transit industry, it may be facing a hard task.

B. COMPUTERS IN TRANSIT MANAGEMENT

The transit industry, along with other types of business, has been involved in the creation of computerized decision-making tools; however, most of the past efforts have concentrated on serving the large transit organization. Software suppliers have found it profitable to scale down accounting, manufacturing control and merchandizing packages originally designed for large firms, so that the typical small retail or manufacturing business has a variety of applicable software packages from which to choose. Small transit operations, however, represent a comparatively limited market and thus have not benefited from the

attention which small business needs are getting.

Development of automated transit aids has taken the form of research grants pursued under the sponsorship of the Urban Mass Transportation Administration. Rucus, an acronym for run-cutting and scheduling, was an early entry in the transit applications field. The Rucus system was developed in 1970 as a modular package of programs designed to address the scheduling aspect of transit planning. Briefly, Rucus comprises four modules [3:150-51]:

1. Trips, to adjust frequency of service in response to demand and company policy;
2. Blocks, to assign vehicles to trips in accordance with an optimization technique;
3. Runs, to assign drivers to trips in accordance with labor contracts and company policy; and
4. Data Management, to interface the other three modules.

While these programs apply to functions shared by all transit organizations, the original Rucus package was designed for large-scale hardware and thus was suitable only for large transit operations. Liberal distribution of the Rucus package to the industry has allowed private enterprise to participate in the evolution of Rucus so that it has since become a generic standard from which customized systems are developed. The addition of report generation to use the schedule information to produce operating reports and timetables has boosted the worth of Rucus-type applications to the industry [4:25]. The area of bus fleet maintenance was also addressed by an Urban Mass Transportation Administration study. In 1971 and 1972, the Administration initiated the SIMS project for transit districts in Oakland, CA, and Dallas, TX. SIMS, an acronym for Service, Inventory and Maintenance System consists of three modules:

1. The Service per Unit Change module uses vehicle miles as the unit of performance. Performance is a function of fuel and oil consumption and parts repair or replacement.

2. The Inventory module is a standard inventory control program to record issuance and receipt of materials and to maintain stock points. Parts repair costs are input to the next module.

3. The Repair Cost module combines labor costs incurred in the maintenance of vehicles with parts costs from the inventory module to maintain lifetime costs on vehicles.

Another computerized transit tool is the Maintenance Planning System (MPS). It produces comprehensive reports for maintenance control, as follows:

1. Maintenance Control reports for preventive maintenance and major repairs scheduling;
2. Equipment Status reports for ongoing vehicle history; and
3. Failure Analysis reports to identify parts with recurring failures.

Both SIMS and MPS were designed for large transit companies; the Oakland and Dallas fleets comprised 800 and 400 buses, respectively, and MPS was tested on San Francisco's BART system. Both systems run on IBM 360/370 mainframes.

Small transit operations are the intended market for Trans-Pac, a complete management package developed by MTD Project Services, a division of Qantel Business Computers. Trans-Pac handles financial management, maintenance and inventory control similar to MPS, driver timekeeping, payroll, Rucus-type scheduling, performance measuring, and Urban Mass Transportation Administration-required reports. It is designed to run on any of Qantel's minicomputers, depending on user's desired speed and memory requirements.

Some packaged software has appeared to meet the general needs of vehicle maintenance for trucking firms and industries with private transportation fleets which may be applicable to transit maintenance as well. These packages

are designed for minicomputers. Judging from sources consulted, the microcomputer software market does not as yet offer vehicle maintenance applications (although an aircraft maintenance package available for Apple computers may signal future involvement in this area). As microcomputer software suppliers expand to cover more vertical markets, more transit operation functions will be computerized. At the present, however, the choices are few.

C. PROBLEM DEFINITION AND OBJECTIVE

As evidenced by the profusion of minicomputer and microcomputer manufacturers, software suppliers, OEMs[1] and consultants, the small business computer market is complex and confusing. A company venturing into the computer arena for the first time must heed the words "Buyer beware." One such company investigating the possibilities of automation is Monterey-Salinas Transit (MST), a publicly-owned, local transit company located in Monterey, California. MST reviewed their present manual record-keeping procedures and concluded that a computerized management information system (MIS) incorporating the individual administrative record-keeping systems associated with each operational area would benefit organizational efficiency and effectiveness [5]. Many of MST's functions parallel those of any other like-sized service or manufacturing firm, but much of the workload addresses transit needs specifically. Due to the prohibitive costs of specialized system design, which would ideally tailor all hardware and software to MST's particular needs, and because of the lack of an in-house programming resource, the company concluded that the only feasible option would be to acquire a system "off the shelf": either

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[1]OEM stands for original equipment manufacturer, which is a retailer who combines hardware and software from various sources to supply specific markets.

one already designed for small transit companies, if such existed, or one compiled for that purpose utilizing commercially available software and general purpose hardware.

It is important, when introducing computerization, to determine which of a company's tasks are cost-effectively transferred to automated processing. Computers are fast, accurate, and incapable of thought, whereas man is slow, error-prone, and thoughtful. This relationship between man and computers suggests that tedious, routine, and time-consuming tasks should be offloaded to the computer so that human resources may be utilized in the business of management. However, due to the high cost of custom software design, some procedures not covered by packaged software are best left to the manual system.

The objective of this thesis is to analyze the trade-offs in cost and performance between two minicomputer and two microcomputer systems designed to meet Monterey-Salinas Transit's requirements to differing extents. One system is specifically designed for small transit operations. This system, Trans-Pac, distributed by Arthur Andersen & Co., is treated in this thesis as the most responsive solution. However, other options exist which may meet some or all of MST's needs at a lower cost. It is beyond the scope of this thesis to develop an operational computer system to compete with the professionally-developed Trans-Pac system. Instead, the four systems aim to be representative of two computer classifications, minicomputers and microcomputer networks. Typical costs and software availability will lead to the development of cost-performance figures to ascertain whether there is a difference between mini- and micro-based systems. This thesis first determines MST's needs in terms of general hardware and software requirements and then uses these guidelines to configure three systems to perform the functions identified in the requirements analysis. These

systems are analyzed in terms of their reponsiveness to MST's software requirements using a weighted evaluation scheme.

D. SOURCES

Information on transit operations and functions was provided by personnel at Monterey-Salinas Transit Company, publications on the transit industry, and a management performance audit [6]. Specific prices, hardware model specifications and software availability were drawn from Data Sources and Datapro Research Corporation's Datapro 70 and Directory of Small Computers. The distributor for Trans-Pac, Arthur Andersen & Co., was helpful in describing the system and providing approximate costs.

II. MONTEREY-SALINAS TRANSIT ORGANIZATION AND REQUIREMENTS

A. ORGANIZATION OF MST

Monterey-Salinas Transit is a publicly owned local transportation company serving the city of Salinas and the cities and county of the Monterey Peninsula. It provides service seven days per week with a fleet of 52 buses and a staff of 100, 70 of whom are coach operators. The company owns two facilities: the main administration, maintenance and dispatching facility in Monterey and a smaller building in Salinas for light maintenance and housing of vehicles overnight. MST is governed by a Board of Directors representing the cities and county served. The Board convenes monthly to review financial and operating data presented by MST's general manager. Additionally, the Board is responsible for approving company goals and objectives, routes and service levels, fares and grant applications.

MST's internal organization is structured along functional lines. The four departments under the general manager are maintenance, transportation, controller, and administration, which includes the planner. The planner is responsible for service planning and scheduling and also computes many of the organization's performance statistics for external reporting requirements. The external reporting function is labeled as part of the administrative function in the system analysis in section B.

In addition to revenues from fares, MST is funded by federal and state agencies. As a result of receiving public monies, MST must account for those grants and allotments in periodic reports. Much of MST's recordkeeping is geared toward providing those reports. Some background on the

federal transportation agency will help define the reporting arena in which MST operates.

The Urban Mass Transportation Administration is an agency of the Department of Transportation, whose chief responsibility concerns the administration of the Urban Mass Transportation Act of 1964, as amended (UMTA). This comprehensive act provides federal assistance for [7:140]:

1. Acquisition and improvement of facilities and equipment associated with mass transportation;
2. Research, development, and demonstration projects related to urban mass transportation;
3. Engineering, planning, and designing urban mass transportation; and
4. Training personnel in managerial, technical and professional positions related to mass transportation.

Since the agency is responsible for allocating considerable sums of federal money through its various grant programs,[2] it is understandably concerned with the utilization of those funds and demands extensive reporting under Section 15, UMTA. Section 15 requires information be maintained on safety and accident claims, annual ridership surveys, detailed classifications of bus driver labor, financial accounts, fares, and profitablility; that is, essentially every aspect of transit operations and management.

Even with the stringent reporting requirements of Section 15, some information was not well enough standardized to permit industry-wide analysis of mass transit. In 1971, the Urban Mass Transportaton Administration, The American Transit Association (ATA), and the Institute for Rapid Transit jointly developed a program to devise an

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[2]Sections of the UMTA address different types of grants: Section 3 for capital, Section 5 for operating and Section 9 for planning grants.

improved system of financial and operating data reporting. The outcome was initiation of Project FARE (Uniform Financial and Reporting Elements), which established a standardized set of accounts and standard operating statistics categories for the entire industry. This data base is designed to serve [3:165] :

1. Federal, state, and local transportation agencies for financial programs administration;
2. Transit industry associations, such as ATA, for monitoring industry performance; and
3. Individual transit systems for evaluating their performance against similar operations

FARE reporting partially meets the requirements of Section 15, UMTA. It is interesting to note that The Project FARE Task IV Report: Task and Project Summary was prepared for the Administration by Arthur Andersen & Co., which distributes Trans-Pac.

B. REQUIREMENTS ANALYSIS

1. Current System

The goal of Monterey-Salinas Transit, simply stated, is to provide reliable bus service in response to public demand. The physical operation of buses along planned routes is supported by a variety of administrative activities, from the planning of service, the acquisition and repair of vehicles, and training of drivers to the ordering of spare parts, payment of employees, and preparation of reports for the board of directors. These tasks are not important to the customer, whose only concern is that his bus is on time, but to MST, they are the administrative functions which allow the transit service to operate. Every firm has its paperwork, a fact often lamented, but a necessity which organizes and documents the management of

personnel, equipment, and monetary resources. MST maintains various files to record day-to-day transactions such as inventory issues, vehicle repairs, and cash disbursements. These files form the backbone of an information system from which information on the effectiveness and efficiency of transit operations can be drawn. An understanding of the manual record-keeping procedures is crucial to successful automation because management must be able to define precisely what services and outputs it expects from the newly automated information system. Monterey-Salinas Transit considers their system of weekly and monthly reports important to effective management, and an automated system should enable creation of those reports. The manual administrative filing and reporting system must record and report meaningful information before converting to a computer system, or the inefficiencies of the current system may be mistaken for unresponsiveness of the computer system. Mere automation of files and reports will not provide better information, only more prompt information. If a company is floundering, automating may only further camouflage the management deficiencies which plague the firm. As one observer noted, "A computer can make a sick business terminally ill" [1:35]. This should not be of worry to MST as a management performance audit performed in 1980 concluded that then-Monterey Peninsula Transit was an exceptionally well-managed system with an extensive formalized reporting procedure well-suited to the company's management structure [6:135-36].

Presently, MST's maintenance, inventory, planning, and personnel filekeeping and reports generation are performed manually. Fortunately, MST is a relatively small organization, well-staffed, so that sheer volume does not overwhelm the capabilities of their current record-keeping systems, and automation is not being pursued to stave off

personnel increases or other methods of augmenting productivity. There are, however, areas which might benefit from the attributes of computerized maintenance. The existence of routine and redundant data handling indicates tasks which would probably gain speed and accuracy from automation. In the case of MST, many of the required performance statistics, generated at least quarterly, necessitate simple but repetitive calculations which are time-consuming and prone to human error. Most other filekeeping requires duplicative entries in various files to allow cross-referencing and to ensure that each file is complete. MST's financial records are prepared by a service bureau, Bank of America, so that accounting applications do get the benefit of computer accuracy and automatic generation. With the advent of in-house accounts processing, data entry would be to a keyboard instead of to paper forms, and the submission and batch processing time lag would be eliminated. Potential savings could result from scheduling payments to take advantage of vendor discounts, if this is not already done. The primary advantage of in-house processing is that the controller would be able to generate non-standard comparison reports, on demand, as opposed to relying only on reports contracted for with the service bureau. The issue of security may have to be addressed since pay records and financial statements should not be available to all users of the system.

The five record-keeping systems to be analyzed for automation are: personnel management, maintenance and inventory control, financial management, service/scheduling control, and the external reporting system. The systems of necessity are interrelated, because information flows and the effects of actions are not solely internal to each department. Thus, mileage figures generated by the maintenance department are used in efficiency reports submitted to the board of directors and inventory purchase orders are

accounted for in the controller's accounts payable file. A brief description of each administrative control system in place at Monterey-Salinas Transit will define the information environment in which an automated system must exist, and the data handling and computational operations which it must perform.

a. Personnel

The aim of the personnel control system is to manage the human resources of the company. Specific activities include:

1. Planning, programming, and administering personnel-related programs;
2. Evaluating employment needs;
3. Evaluating candidates for employment;
4. Training employees;
5. Analyzing compensation levels; and
6. Evaluating employee performance.

A major part of the personnel system is geared toward accurate and timely payment of employees, which necessitates withholding taxes, collecting Social Security contributions, and deducting payments for insurance, pension, or other benefit programs. The payroll system must register changes in salary or wage, job, seniority, and other personnel shifts. Beyond payroll activities, the personnel system is designed to facilitate production of the detailed reports required by the federal government under employee protection programs, such as Equal Employment Opportunity (EEO)-Affirmative Action (AA), and Section 15, UMTA. As driver labor accounts for a considerable percentage of a transit system's operating expense, detailed records on how drivers spend their time are maintained in accordance with UMTA regulations. Operator timekeeping must account for 21 categories of compensated time to be reported

to the Urban Mass Transportation Administration, while each driver's compensated and non-compensated time is recorded in an attendance file, corresponding to one of seven categories per day. The files currently in use to support these personnel and reporting functions are shown in Table IX , Appendix A.

b. Maintenance

The objective of the maintenance department is to ensure that sufficient vehicles are maintained in a safe and efficient condition, at a reasonable cost, to meet scheduled service. Specific activities include:

1. Repairing service breakdowns on an emergency basis;
2. Conducting a preventive maintenance program (PM);
3. Maintaining service records on vehicles;
4. Maintaining control over repair parts and fluids in inventory;
5. Monitoring fuel, oil, and automatic transmission fluid (ATF) consumption; and
6. General upkeep of property to include plant and bus stops.

The maintenance administrative system is set up to keep extensive records on vehicle service and repair to facilitate planning and monitor vehicle efficiency. Preventive maintenance is scheduled on the basis of daily inspections and a "tickler file" to alert personnel to upcoming mileage or time checks. Unscheduled or emergency repair, for which personnel and parts must be on hand, and replacement buses available, may result from manufacturer directives or breakdowns. In any circumstance, bus non-availability must be transmitted to the dispatcher for use in bus assignment, and repairs effected under warranty must be documented for reimbursement. Labor and parts costs currently are not charged to each vehicle to allow lifecycle

costing, as the use of standard labor hours and costs are not fully incorporated into the manual system. Additionally, the tracking of major components--engines and transmissions--for evaluation of equipment reliability is not covered by the maintenance system although MST wishes to integrate both of these controls into an automated system. In addition to ensuring that vehicles are available for service, the maintenance system is organized to provide efficiency reports to management. Mileage and fuel and oil usage and inventory status are reported monthly for input to the planner's computations of performance statistics.

The maintenance department is also responsible for managing inventory and equipment. The objective of inventory control is to reduce obsolete items, store and protect inventory supplies, and improve forecasting to establish minimum levels of stock while avoiding outages or delays in availability. Currently, a cardex file is used to record receipt and issuance of parts and supplies. Due to the easy availability of parts, secure supply channels, and the maintenance clerk's familiarity with vendors and parts usage rates, order points and order quantities have not been developed. To reduce the cost of inventory and provide an inventory control system independent of specific employees, the inclusion of minimum stock points, order quantities, and automatic generation of purchase orders in an automated system is desirable. The documents and files supporting maintenance administration are described in Table X , Appendix A.

c. Finance

The objective of the financial function is to plan for and ensure the efficient utilization of funds. The objective of a financial reporting system is to provide a structured method of accountability and a basis for judging

operations. MST's financial functions are budgeting, accounting of revenues and expenditures, internal control for the safeguarding of assets, and the application of federal monies. Financial reporting and accounting must conform to generally accepted principles of accounting and to the reporting requirements of the UMTA and California Transportation Development Act of 1971.

These functions are currently performed under a contract with a service bureau. The controller compiles data for input to the service bureau twice a week. Updated ledger accounts are returned and monthly financial reports are created. The controller uses standard files to maintain the accounting data as shown in Table XI , Appendix A.

d. Plans

The objective of the planning function is to turn the company's objectives into concrete courses of action. This is pursued in two stages: setting service levels and scheduling resources, labor, and vehicles to meet the service level. In support of the first task, the planner conducts an annual ridership survey to determine the degree to which existing routes and schedules respond to demand. The surveys gather information on fare categories, load factors, time and spacing of stops, which, together with data on operating expenses, generates figures to determine which routes are cost-effective, where zone lines should be drawn, and optimum frequency of service. A programmable calculator is used in the manipulation of the numbers recorded during the survey, but the compilation process can continue through several weeks and perhaps months. Given these utilization figures and associated costs as well as community input, the planner evaluates the present level of service against demand and fiscal constraints to recommend continuation, adjustment, or

deletion of routes. Once levels of service are set, the planner must determine how the various routes should be allocated to drivers and buses in segments called "runs." Run-cutting must try to maximize driver productive time while minimizing overtime and conforming to provisions of the labor contracts, all subject to the established route structure. Obviously, this is a time-consuming process, and it will usually require revision during holiday periods and after the ridership survey. In support of these functions, the planner maintains several files shown in Table XII , Appendix A.

e. Administration

In the general administrative system, data originated by the other functional systems converge. At this point, their outputs are combined and interpreted to facilitate internal management decision-making and external reporting. Data on materials usage, miles and hours of vehicle service performed, accidents, breakdowns, and expenses enable management to compile measures of performance to facilitate reporting under the Urban Mass Transportation Act of 1964 (UMTA), as amended, and California's Transportation Development Act (TDA) of 1971, and to present information for management decisions affecting service, purchasing, federal grants, and marketing. Several types of data maintained for input to the quarterly and annual performance reports provided the Board of Directors and governmental transportation departments are shown in Table XIII , Appendix A. The formatting of this information into formal reports is manual. The creation of the statisics drawn from files would be easily supported by automated report generation.

2. Indicators of System Size

Some general constraints must be acknowledged before attempting to fit a computer to users' requirements. Decisions as to on- or off-line data retrieval, real-time or batch processing, if made early will channel initial investigation toward systems built upon those characteristics. The decision by MST to acquire an on-line, real-time system directs their attention toward a disk-based system utilizing CRTs for entry. But this category is still too broad to allow a manageable comparison of alternatives. Other descriptors and constraints must come into play. Obviously, cost is one such constraint; an organization with a budget of $100 does not spend time evaluating a $1000 system. Similarly, Chase Manhattan Bank does not consider loading its database onto a few 8-inch floppy diskettes. Key volumes of a system such as size of a database and the number of users serve to further define the range of feasible alternatives.

The number of users for whom the system is planned is based upon the functional breakdown of tasks as MST is currently organized. At a minimum, entry to the system is to be made in five locations:

1. Maintenance department for inventory and vehicle maintenance records update;
2. Comptroller's office for financial functions;
3. Operations planner's office for level of service planning and performance analysis;
4. Administrative department for general personnel functions and word processing; and
5. Remote entry from the Salinas facility, primarily for update to the inventory and maintenance records.

The determination to serve a minimum of five users effectively bounds the range of feasible options by eliminating

single-user microcomputers from the low end of the scale and by suggesting that systems oriented to serving hundreds of users, at the high-end, would likely not be cost-effective.

Storage capacity required to hold the data and programs creating the system is another guideline to use in identifying possible computer configurations applicable to MST. Some processors, notably microprocessors, are limited in the amount of secondary storage they can access, and may only support floppy diskette or cassette tape storage devices. MST's secondary storage requirements may be estimated from the number of characters which compose the files to be stored, incorporating some growth factor over the system life.[3] Datapro Research Corporation [9:SC15-200-108] recommends the following formula: Disk storage equals

1. the number of data file characters; plus
2. 25% of the number of characters to allow for indexes or sections of the disk required by the computer to perform random access; plus
3. 20% of the number of characters for program storage; plus
4. 20% of the number of characters for work files for sorting or storage of temporary data.

Thus, disk storage equals 165% of the original data characters, with the total rounded up to the next higher million bytes for safety. To arrive at the number of characters of data which will be held in MST's computerized database, the "brute force" method was applied: The average number of characters per field were summed to produce an average number of characters per record for formatted records such as fixed assets. Unformatted records without delineated fields, such as training records, were estimated at an average number of characters per record. These counts for

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[3]A system's economic and planning life should be considered to be approximately five to eight years [8:132], though the changeable nature of computer technology may suggest that any given system would be obsolete before that range was reached. Datapro advocates a five-year life and that figure is used in these calculations.

each type of record were then multiplied by the number of records in each file to arrive at an estimate of the number of characters per file. The addition of these figures results in a total of 10 million characters which, at one byte per character, equals 10 megabytes of data. Applying DataPro's formula, the following figures are generated:

Disk storage equals

1. 10 million characters which, assuming a nominal growth rate of 5% per year[4] over a 5-year lifecycle yields a fifth year total of 12.761 million data characters; plus
2. 3.190 million for indexing
3. 2.552 million for program storage; plus
4. 2.552 million for temporary work files; equals

21.055 million characters. After rounding up, the rough total is 22 megabytes of disk storage. This figure represents sufficient storage for currently planned usage of the system, but allows nothing for growth outside the bounds of the foreseen system. New uses, new applications of the hardware could not occur without buying more storage. This proposition is more complex than it sounds if the system's addressing capabilities or disk controller, for example, will not support additional secondary memory. Common sense dictates that expansion should be planned for, and although MST does not foresee any growth in service or employees, experience shows that, once installed, users will find more and more uses for the computer. One study indicated that the overall system cost is minimized if the hardware provides 50% to 100% more capacity than is absolutely necessary [10:13]. Using this range gives a final figure of 33 to 44 megabytes of secondary memory, in the form of disk

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[4]The 5% figure is taken from the fixed assets account which, with additions of 40 and retirements of 5 accounts per year, shows a growth of 35 accounts on a total of 700, or a 5% increase.

storage for on-line retrieval, as a reasonable estimate to be used in configuring alternative computer systems for MST.

3. Application Areas

The key to the performance of, and user satisfaction with, any computer system lies in the software running on it. Small business users typically do not shop for raw processing capacity, but rather look for specific software to fit their needs and simply buy whatever hardware will support it. The cost of a small business computer system may be drastically reduced if packaged software, as opposed to custom software, is used. According to one market analyst, standard software prices are about one-third the cost of specially produced software [11:92]. Unfortunately, with almost any packaged programs, there will not be an exact fit between the program designer's conception of standard procedures and the individual user's procedures. Regardless of which procedure is "standard," one consultant recommends the 80/20 rule: if 80% of the package fits the user's requirements, it may make sense to modify requirements to take advantage of the package as is [1:36]. Of the following application descriptions for Monterey-Salinas Transit, some, like general ledger and accounts payable, may actually fit standard packages, which makes location of a supplier simple. Some, like inventory control, may be general enough to allow the use of standard software with a few changes in current procedures. For some unique applications, there are no "near-fits" so that custom software is the only option. In these cases, economic theory dictates that MST not automate those applications for which the cost exceeds the value received. This entails a cost-benefit analysis of each application in which MST must quantify the benefits of computerized versus manual handling.

The description of MST's manual filing and management control system in section A defined the environment into which an automated system must be assimilated and prescribed what functions the system should provide. The translation of these functions into applications packages available for off-the-shelf systems configurations is performed below.

a. Personnel

There are a variety of payroll and personnel packages on the market; some are integrated to maintain personnel information and make available to the payroll calculations such data as is necessary. Payroll disbursements may then update the financial accounts. Non-integrated applications can be combined to cover the same functions; separate applications for payroll, personnel records maintenance, and financial records. Special EEO-AA applications exist to set up equal opportunity goals and prepare required government reports. The remaining personnel-type records may be maintained on disk for access by a report generator for summations and sorts. Operator timekeeping presents a problem to "canned" timekeeping routines which are not structured to maintain the 21 categories MST would require. It is doubtful that any standard program could accommodate the timekeeping requirements.

b. Maintenance

Maintenance administration would benefit from a vehicle maintenance program to track lifecycle costs on each vehicle, establish labor standards for maintenance activities, and track tire life, engines, and transmissions. A separate application would schedule preventive maintenance at the mileage points stipulated by MST. An inventory control application generally will maintain stock levels,

calculate usage rates and variance from expected rates, and may automatically generate purchase orders for items below required stock levels. In other instances, the purchasing function may be handled by a separate application.

c. Finance

An automated financial control system would provide those services which the service bureau now handles: general ledger, accounts payable, fixed asset accounting, and payroll. Accounts receivable need not be automated if the recommendation of one software house president is taken. He suggests that a volume of less than 10 to 15 invoices per month does not warrant accounts receivable automation [12:72]. Some financial reporting, such as balance sheet preparation, is available with almost all general ledger programs; however, most of the specialized reports dealing with federal grants under the UMTA would not be automatically produced at the punch of a button. They could, however, be compiled from information residing in the data base via report generation.

d. Plans

The planning function is unique to the industry, and not easily satisfied by general-purpose software. As the history of computerized transit management shows, customized applications for this function were designed within the construct of a complete system, primarily for mainframe computers, eliminating the opportunity to pick and choose among individual route planning packages for smaller systems. However, a general-purpose electronic spread-sheet could assist in tabulation of the ridership survey figures used in determining demand and service utilization. The ridership survey requires manipulation of a matrix of 13 columns by a variable number of rows. The columns record

data on fare category, number of passengers on board, how many deboarded, time of day, and other information for each of the bus stops listed in the rows. These columns and rows are prepared for every bus route to compute various ratios: average load (number of passengers over the number of seats), passengers per mile or passengers per hour. The computations are elementary, but there are many of them.

The scheduling function, like planning, is transit-specific. Of the several run-cutting programs developed from the original RUCUS model, none have been designed apart from a customized transit system, again, primarily for mainframes, and so are not available for off-the-shelf system design.

e. Administration

The administrative reporting demands may be satisfied by a report generator or data base management system (DBMS) query language facility to allow data from maintenance, planner, personnel, and controller files to be aggregated. A DBMS will allow individual fields from different files to be combined as the requirements dictate. For example, expense data can be drawn from the financial files for combination with mileage data maintained in vehicle files to create the efficiency statistics called for by the state transportation department. For general clerical requirements, the administrative system would benefit from the capability to perform word processing: the encoding, formatting, editing, printing, and storage of communications using computer-based hardware and software. This would be used to greatly reduce preparation time of monthly correspondence, two large annual reports, multiple mailings, coach operator schedules, and templates for printed forms.

III. PRESENTATION OF ALTERNATIVES

A. GENERAL

This chapter presents four alternate computer systems which address Monterey-Salinas Transit Company's reporting and record-keeping needs in varying degrees of completeness. The four choices fall into two classes of computer systems: minicomputers and microcomputer networks. Although distinctions are blurring between classes of computers based on size (is it a low-end mini, a supermini or a mainframe?), the idea of a traditional minicomputer configuration is sufficiently well-understood to not warrant elaboration. However, the concept of a network, particularly a microcomuter local area network, is not so widely concurred upon, and at this point, the terms and distinctions deserve brief explanation.

B. LOCAL AREA NETWORKS

A local area network, or LAN, desribes an interconnected collection of autonomous computers joined within some limited geographical area, generally accepted to be less than a diameter of 10 km. or six miles or so [13:102]. LANs evolved from the longrange telecommunications networks developed in the 1960s. As universities and research labs began installing computers to assist in their operations, the need arose to share information between them. This was handled by passing packets of information[5] across a

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[5]Packet is the term used to refer to blocks of digital data to which routing information and error-detection fields are appended. The user is unaware of the breakdown of his messages into packets for transmission and of the subsequent reassembly at destination as those tasks are functions of the network software.

communications link between host computers. Network developers had to ensure that packets were delivered to the correct destination, that they were reassembled into complete messages or files in order, and that packets did not collide or could recover from collisions with other packets using the medium.

Various schemes were developed to control access to the network, detect and correct collisions, and ensure complete and correct transmission. The first commercially successful local area network was Ethernet, introduced by Xerox in 1979. Ethernet is a passive communications medium, i.e., not controlled by a master CPU (central processing unit) and not relying on switching logic to serve its stations. The Ethernet network simply accepts transmissions from attached nodes,[6] each of which controls its own communications transceiver. A transmitting node monitors the channel for traffic and sends when the channel is idle; the receiving node accepts packets with its address, ignoring all others, and acknowledges correct receipt to the sender [14:138]. If any one of the system nodes fail, the others are not affected. Ethernet was designed to be simple and reliable, yet such a scheme is obviously more complex than simple point to point communications where every link is a dedicated channel.

Two commonplace alternatives to LANs are products which provide multi-user processing and resource sharing but not the complete computer interaction which is the keynote of true networks. One implementation installs several microprocessor boards and memory boards in a chassis. One microprocessor is usually reserved for controlling shared access to the central disk and printer, and terminals are

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[6]The word "node" is used here to suggest any number of devices: mainframe, mini- or microcomputers, front end processors, terminal control units and peripherals, for example.

connected to each remaining processor so that each user on the system has a dedicated CPU. This method, though inexpensive, offers few of the advantages for which microcomputer networks are chosen. Users cannot utilize private printers, floppy disks and the like, nor can they directly communicate with each other, save by going through the common service processor. Worse, if any of the modules in the central unit fail, generally the entire system is down.

The other product is the disk multiplexer where several microcomputers are multiplexed into a disk controller, which controls access to one or more hard disk drives. A disk multiplexer may be likened to a fast rotary switch which cycles around, checking each attached workstation for a signal requesting disk access. The multiplexer processor services the request and is then free to resume cycling [13:95-96]. As with the central microprocessor chassis implementation, separate stations cannot communicate without routing information through the multiplexer, either to the disk and back out to the destination station or to a buffer and back to the destination. But this implementation does provide an added measure of reliability in that individual microcomputers may fail without interrupting data transfer and computation for the others. Only if the central disk or multiplexer fails does all work stop; this risk is a tradeoff in cost and complexity which many organizations may be willing to make. It is these sorts of cost tradeoffs in hardware, as well as the software performance differences between a custom designed system and off-the-shelf systems which are examined in the analysis of the following four computer systems.

C. THE COMPUTER SYSTEMS

1. The Minicomputers

The first system is a professionally developed transportation management system called Trans-Pac, distributed by Arthur Andersen & Co. Trans-Pac is applicable to public and private transit operators with from 20 to 500 vehicles, and is designed to be used by regular transit company staff with no computer expertise. The system runs on Qantel hardware which is configured to fit the size of the individual companies. Thus, it can run on Qantel's Series 200, 300, Model 960/965, or 970/975 minicomputers fitting a wide range of terminal and disk storage requirements. For a company the size of Monterey-Salinas Transit, the recommended package would include 128K (kilobyte) of random access memory (RAM), 40M (megabyte) disk drive, 5 CRTs, a magnetic tape drive for backup, and a 120 cps (character per second) serial printer. (A letter-quality printer is also desirable but is not included in the package price.) Modems are not manufactured by Qantel but the system accepts data communications equipment rated below 9600 baud. The Trans-Pac software is written in Qantel's version of BASIC called QICBASIC. Applications cover every facet of transit management, specifically:

1. Payroll and personnel: operator timekeeping in all categories, tax and voluntary deductions, overtime for pay and UMTA reports, accident and incident files;

2. Financial records and reports: general ledger, accounts payable, accounts receivable, fixed asset accounting and depreciation, and UMTA Section 15 reports;

3. Maintenance: preventive maintenance, fuel consumption reports, lifecycle vehicle parts costing, labor and materials usage tracking, inventory control;

4. Planning: routing and runcutting, processing of ridership surveys;

5. Reporting: revenue and ridership reporting, accident and safety reports, Section 15 financial, labor, efficency and scheduling reports, and report generator.

The software comes as a package bundled with the Qantel hardware. Arthur Andersen & Co. breaks down the total system price into $70,000 for hardware and system software, and $20,000 for applications software. An additional fee is charged for implementation and user training. A summary of the costs is presented in Table I .

TABLE I

Trans-Pac Hardware and Software

CPU	Model 965 8-bit word, 128K RAM, 32K ROM with operating system and language partially implemented in firmware, time-shared (not multiprogrammed)	
Speed	Add time	8.0 microseconds
	Memory cycle time	1.5 microseconds
	Maximum I/O rate	900K words per second
Capacity	Disk cartridge	40M
	Terminals (27 x 54)	5
	Tape 36K - 72K bits per second (bps)	
	Printer	120 cps
Cost		
Hardware	Qantel package	$70,000
Software	Sort, utilities, compiler	included
	Trans-Pac applications	$20,000
Total		$90,000

The Wang 2200 Series is aimed at first time users with general business requirements. The 2200 MVP model will support 13 users utilizing a 16-partitioned memory scheme to provide true multiprogramming. The system may be expanded up to 512K of main memory and supports 480M of disk storage. Interactive terminals with business graphics characters and a wide base of Wang and independent supplier data and word processing software make this system well suited to the business environment. The system includes either a BASIC or COBOL interpreter and operating system implemented in ROM (read-only memory) which frees the available RAM for user

TABLE II

Wang Hardware and Software

CPU	Model 2200 MVP 8 bit data memory, 24 bit control memory, 128K RAM, 64K ROM, fixed partitioned memory management for multiprogramming		
Speed	Add time		13 msec
	Memory cycle time		.6 msec
	Maximum I/O rate	100K words	per sec
Capacity	Disk drive		30M
	Terminals (24 x 80 plus 64 graphics characters)		5
	Printer		180 cps
	Tape drive	55K - 130K	bps
Cost			
Hardware	CPU	12000	
	terminals @ $2700	13500	
	disk	17000	
	printer, controller	3700	
	tape drive	13000	
	Total		$59,200
Software	Wang Integrated Information System (sort, 10 utilities, 6 subroutines)		no charge
	Applications		
	integrated business package (GL,AP,IC,PO,FA)	8000	
	payroll	1500	
	vehicle maintenance and efficiency system	8000	
	electronic spreadsheet	5000	
	word processing	1500	
	report generator	4500	
			$28,500
Total			$87,700

Note: GL-General Ledger AP-Accounts Payable
IC-Inventory Control PO-Purchase Ordering
FA-Fixed Asset Accounting

processes. Wang offers modems for remote data communications, as well as several printers. In order to make this system comparable to Qantel's, similar capacities were chosen for the configuration. Off-the-shelf software was found for most computing and file keeping applications, but obviously programs to format and report specific data elements for UMTA Section 15 and other transit company routine reports is not available. Custom tailoring is necessary for those functions. The hardware and software

specifications are summarized in Table II . The Wang report generator for this model computer costs $25,000. This price would easily throw Wang out of the running, so a package for similarly sized hardware was substituted on the supposition that a vendor would be able to find a reasonably priced package.

2. The Microcomputers

The two microcomputer configurations presented below do not differ appreciably in the cost of applications software. Microcomputer software runs within a predictable price range of $100 to $800 per application (and heavy competition creates sizeable discounts), with some outlying figures for specialized programs for which the market is limited. Similarly, software designed for proprietary operating systems and languages may tend to cost more than that designed to run on widely used products such as the de facto standard microcomputer operating system, CP/M, because the costs cannot be spread over as large a customer base. It can be concluded then, that where the two micro networks do differ in cost, it is a function of the hardware and associated system software, and not of the applications.

A simple device-sharing microcomputer network is Intertec Data Systems' CompuStar Microcomputer System. The CompuStar network consists of up to 255 microcomputers called video processing units (VPUs) daisy-chained together to share the resources of a single hard disk device. CompuStar allows multiple users to access the common data base while allowing individual users the ability to maintain private files on local floppy diskettes up to 1.5M. CompuStar may be configured around one of three disk storage systems: 10M Winchester disk or a 32M or 96M Control Data Corp. disk cartridges. All are equipped with a disk controller and multiplexer circuit to tie user stations into

TABLE III

Intertec CompuStar Hardware and Software

CPU	Model VPU 20 Z-80A processor, 8-bit word, 64K RAM utilizing CP/M in Microsoft BASIC			
Speed	Data transfer rate			1.6M per sec
	Add time (approx.)			1 - 2 msec
	Memory cycle time (approx)			.2 - 1.6 msec
Capacity	Disk cartridge w/controller			32M
	Terminals (VPUs)(24 x 80)			5
	Printer			120 cps
	Tape drive			48K bps
Cost				
Hardware	VPU 20 @ 3000	$15000		
	disk	12000		
	printer	2000		
	tape cartridge	2500		
	total			$31,500
Software	text editor			no charge
	Applications	Low	High	
	general ledger	100	800	
	accounts pay	100	800	
	payroll	100	400	
	assets/depreciation	400	800	
	inventory control	140	800	
	purchasing	140	400	
	modeling/spreadsheet	200	300	
	word processing	250	500	
	report generator or DBMS query	400	2000	
	total	1830	6800	
	weighted average: 70% low; 30% high = weighted avg			$3,300
Total				$34,800

the disk. As a disk multiplexed system, CompuStar avoids the complexity of true networked systems as well as the somewhat higher price, but also gives up the advantages of direct communication between workstations and distributed processing. The system is expanded simply by connecting another workstation to the network circuit. Connections on each VPU are independent of terminal operation so that failure of a VPU does not affect others. Intertec's VPUs are 8 bit processors offering 64K of RAM and running CP/M with a choice of Microsoft BASIC, COBOL, or FORTRAN.

Intertec does not offer printers but the system accepts any RS-232C interfaced printer running at 9600 bits per second, or slower. Modems for remote system entry are also available from other suppliers. Typical costs for one configuration of the CompuStar system are shown in Table III . Software prices are shown as high and low figures. Since high prices are rarer than low-end prices, and since CP/M-compatible software in particular seems to benefit from prevalent discounting, a weighted percentage is applied to each subtotal to produce a weighted average price.

The Nestar Cluster/One Model A is a true local area network based upon Ethernet principles, but implemented on Apple (or in the near future, IBM) personal computers. The system includes integrated software and hardware features needed to handle data processing and data communications. Workstations can operate independently with a full complement of local peripherals, such as floppy disks and printers, or as participating network members with a share of the common data base and peripherals. The network includes a number of network "servers," defined as any of the network stations which provide services--such as printer support, disk access, data base managment system access--to other stations. The servers are distinguished from other stations merely by the software they run [13:108-10]. To provide access to the hard disk storage, one of the Cluster/One stations must operate as the network file server. Other software creates a print server to make a number of printers available to the network. Network programs may be executed under Apple's DOS (disk operating system), and SOS (sophisticated operating system), UCSD-pSystem or CP/M operating systems, a flexibility which provides a sizeable pool of software support. Apples are fitted with an expansion card for each operating system desired, and users can switch at will between operating

TABLE IV

Nestar Cluster/One Network Hardware and Software

CPU	Apple II 8 bit word, 64K RAM, 12K ROM Assembler and control program partially implemented in ROM	
Speed	Transmission rate	240K bps
Capacity	Disk drive subsystem	33M
	Monitors (24 x 80)	5
	Printer	100 cps
	Tape cartridge drive	240K bps
Cost		
Hardware	Cluster/One package	$33,500
	Printer	2,500
Software	sort, assembler, file server	no charge
	print server software	1,000
	Applications The same software costs as in Table III apply since this network can use the same CP/M software priced in the CompuStar system as well as Apple-compatible software, which is priced similarly. Total (weighted average)	$3,300
Total		$40,300

systems. For connection to the network, each micro must have an interface board in which network protocols are executed. The system boasts increased reliability because no one critical component must execute for network communications to take place. If the actual disk hardware fails, then as in any system, the system fails; but individuals stations may be removed, turned off, or may fail without interrupting transmissions from other nodes. Cluster/One is expandable up to 65 users with secondary storage of 66M per file server. Additional file servers can be added for virtually unlimited disk storage. The Cluster/One package comes with Apple CPUs, Apple or other manufacturer video monitors, a sealed hard disk, tape cartridge for backup (a single cartridge can write and check over 20M bytes of data in 12 minutes), network interface cards, cable and connectors.

Addition to the network is the cost of the Apple plus $395 for an interface card. Typical Apple and Nestar costs for the chosen configuration are shown in Table IV .

D. ASSUMPTIONS

The following assumptions were made in the development of the three "pseudo-systems" and for deciding what costs were included in the comparison of the four systems. Disagreement with the author's assumptions may invalidate portions of the analysis.

1. Compatibility of software with hardware is based solely on a software package's stated compatibility with hardware
   a) manufacturer,
   b) operating system,
   c) language, and
   d) main memory requirement, if given.
2. Compatibility of hardware is either expressly stated or based upon standard interfaces and I/O (input/output) restraints.
3. Some hardware and software elements apply equally to all alternatives and are not broken out separately for cost analysis. These items include:
   a) modems and the phone line for link to Salinas facility;
   b) letter-quality printer for which costs differ by manufacturer, but are roughly the same for equal performance. The printers included in package prices are of lower quality for routine printing;
   c) implementation and training costs, because they apply to all systems and vary widely by supplier and degree of assistance desired.

4. Trans-Pac is considered to provide 100% performance even though some of its features are not optimum, (e.g., the report writer function does not compile to the CRT or disk, only to the printer).
5. The functions of a particular software package can only be guessed from the sketchy descriptions given in source catalogues. Unless stated otherwise, applications are stand-alone, non-integrated packages.
6. Software and peripheral prices vary widely and costs used in this analysis can only be approximations. The intent is to provide typical costs and general availability of equipment and software.

IV. ANALYSIS AND CONCLUSIONS

A. ANALYSIS OF ALTERNATIVES

The bottom line costs attached to each of the four alternatives presented in the preceding chapter do not tell the whole story. If the systems were of equal performance, the decision maker would pick the lowest cost alternative. As they are not, this section analyzes the tradeoffs in cost and performance in order to arrive at a cost-performance curve.

Software performance is the main ingredient in a successful system and in a situation such as MST's, where no in-house programming or fine-tuning of software is possible (without hiring a programmer), the fit of the software to company needs is the essential factor in determining performance of the system. Since both microcomputer networks are assumed to utilize equally capable software, the software performance figures for the two systems are necessarily the same. Thus, differentiating between the two based on software performance is pointless as they are virtually indistinguishable. In the following comparison of the systems, CompuStar and Nestar Cluster/One are combined under the heading "Micro Networks." Each of the resultant three systems is graded on its responsiveness to Monterey-Salinas Transit's software needs, as described in Chapter II. To establish the grading scale, each applications area is assigned a number of points out of 100, and each competing system is then given a percentage of those points to reflect how well it meets MST's functional requirements.

Assigning points to each functional area requires that an assessment of each function's impact on transit management be made. It is simplest to equally divide the 100 points between the five applications areas (personnel and payroll, maintenance, finance, planning, and administration), but, in the author's opinion, this would not accurately reflect the relative importance of the functions. The following discussion presents one weighting formula used in the succeeding analysis and justifies its choice. Using these weights, the allocation of points to each system is made based upon the capabilities of the individual software packages included in the system specifications compiled in Chapter III. However, both of these numerical assessments are subject to change. Other users may value the application area weights and the point allocations differently from the author, resulting in widely varying scores for the alternative systems. To lessen the impact of the subjective nature of the numbers, two weighting formulae and two point allocation schemes are used in the analysis of the cost-performance tradeoffs. So while the numbers generated may not conform to every decision-maker's view of software performance, the method employed is illustrative of the process of cost-performance determination and may be used regardless of the decision-maker's preferences.

It is estimated that over 80% of a transit property's total operating budget is directly and indirectly influenced by the schedule, in terms of service levels set and resources (labor and equipment) used. Optimization of these scheduling processes may save a company 3 to 5 percent of system operating costs [4:19]. Manual scheduling and service planning are extremely time-consuming, a fact which further boosts the importance of automated scheduling. For these reasons, a Rucus-type capablility is considered by the author to be the most important use of MST's automated

system, and is assigned 30 percent of the 100 software performance points. Maintenance of the bus fleet is the second most costly function and an application to encompass the necessary maintenance scheduling, record-keeping, and fuel efficiency monitoring is useful for both routine maintenance decision-making and periodic efficiency reporting. The author assigns this capability 25 points. Inventory control is another time-consuming task; inventory levels must be continuously updated to ensure that stock-outs of parts and fuels do not occur. A benefit of an inventory control package which interfaces with the maintenance records is that complete cost profiles of vehicles are always available. Such an application is assigned 12 points. Financial reporting and accounts maintenance are critical to every business, both for internal control and to comply with external reporting responsibilities. In addition, an accurate and timely payroll is necessary for employee satisfaction and loyalty. Accordingly, accounting functions are assigned a value of 18 points. The large volume of reports generated by MST makes the capability to capture, sum, average or in some fashion manipulate, format and print data a very attractive timesaver. Trans-Pac is obviously the only system to format reports specifically for UMTA, Section 15 requirements, but a report generator accessing all files will be able to approximate this feature. This capability is assigned 15 points. The weights and the corresponding points allocated to each alternative within each applications area are shown in Table V . The applicability to MST's specific requirements, and the degree of software integration are the main factors which guided the author in grading each alternative. Additional notes are provided to explain specific point allocations. A plot of the performance scores versus the cost of each alternative, calculated in Chapter III, is displayed in Figure 4.1 .

TABLE V

Software Performance Scores

	Trans-Pac	Wang	Micro Networks
Scheduling Support (30)	30 (100%)	4.5 *a (20%)	3 *b (10%)
Equipment Maintenance (25)	25 (100%)	22.5 (90%)	4 *c (15%)
Inventory Control (12)	12 (100%)	10 *d (85%)	8.5 *e (70%)
Finances and Payroll (18)	18 (100%)	14.5 *f (80%)	13.5 *g (75%)
Report Generation and File Maintenance (15)	15 (100%)	10.5 *h (67%)	10.5 *h (67%)
Total	100.0	62.0	39.5

Notes:
a. electronic spreadsheet for number manipulation only
b. same as above; micro version less powerful
c. allows vehicle files to be held, but no automatic maintenance scheduling or exception reports and IC; no maint.
d. integrated purchasing and inventory control (IC), but no maintenance interface
e. separate purchasing and IC, and no maintenance interface
f. standard accounts and payroll, but financial reports not transit-specific; integrated package
g. same as above but not integrated
h. manual formatting and information compiliation of reports,(e.g., UMTA reports)

The "best choice" decision, though not directly readable from the graph, can be quantified by determining how much additional cost is incurred by moving from a lower-performing system to the next higher system. This is the marginal cost of the higher-priced system in terms of the amount of performance increase, i.e., the additional cost per unit of performance gained. The marginal cost of the lowest-priced system (the microcomputer alternative) would be determined by computing the difference between its cost and the cost of the current manual system, if that were known, in terms of the increase in performance levels, if that were known. Thus, the cost-performance curve in Figure

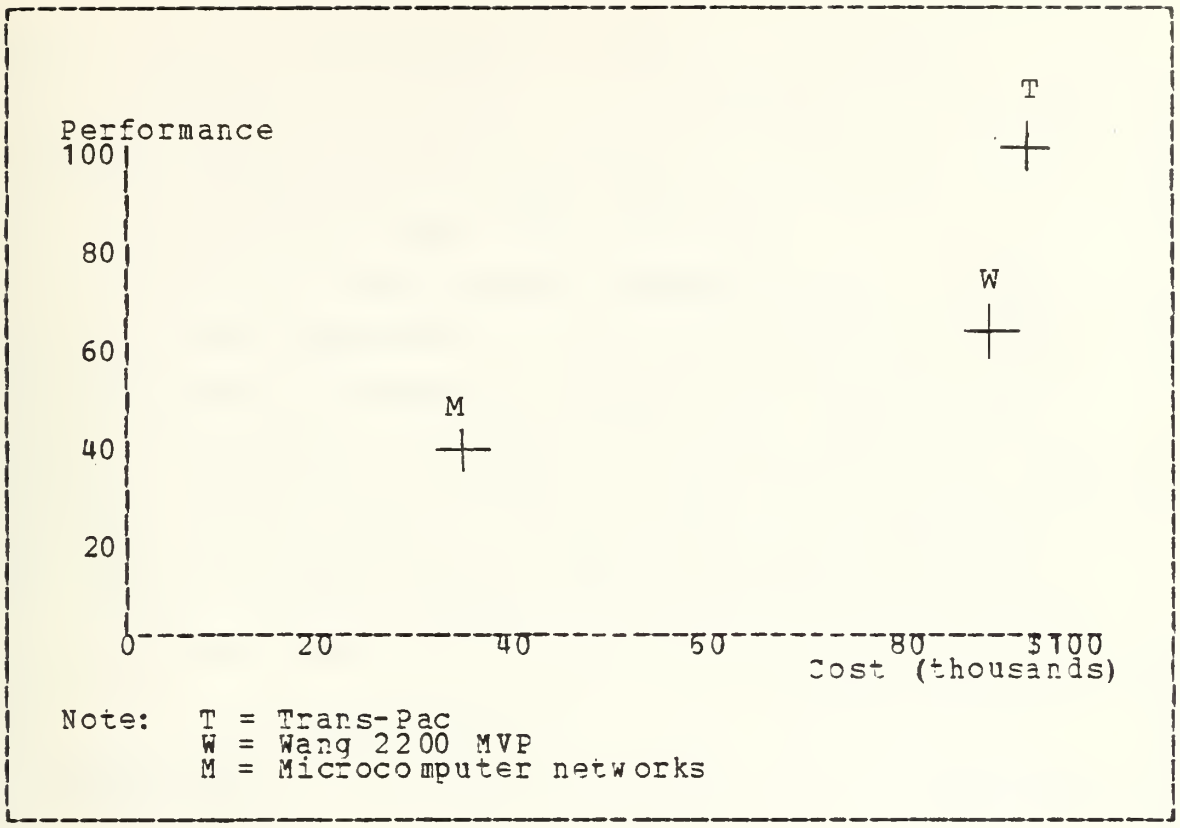

Figure 4.1 System Performance vs. System Cost.

4.1 shows that in moving from the Micro Network alternative to the Wang system, 22.5 additional units of performance are gained at a cost of $52,900.[7] The cost of gaining 38 more units of performance by moving from the Wang system to Trans-Pac is only $2,300. The marginal cost of moving from the microcomputer system to Trans-Pac is the sum of the above changes, or $55,200 for 60.5 additional performance points. Without further analysis, the low marginal cost of selecting Trans-Pac over the Wang alternative suggests that Wang would not be selected. Without knowing the individual

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[7]This figure is the result of subtracting $34,800 from Wang's $87,700 cost. $34,800, the cost of the CompuStar alternative, is the lower cost for that performance level; it is not reasonable to pay more than necessary by buying the Nestar system.

user's value of performance, however, is impossible to say which alternative is "best": if performance at any cost is desired, then the Trans-Pac system is obviously that user's choice; if maximum performance for $15,000 is the goal, then none of the alternatives are acceptable.

The marginal costs between systems change in response to changing user assessments. Due to uncertainty in both price and performance figures, the points on the graph are no longer discrete, but become blurred as a result of the numbers' sensitivity to change. First, each point covers an expanded vertical space to account for the variability of the costs; this due to the estimation method used and to

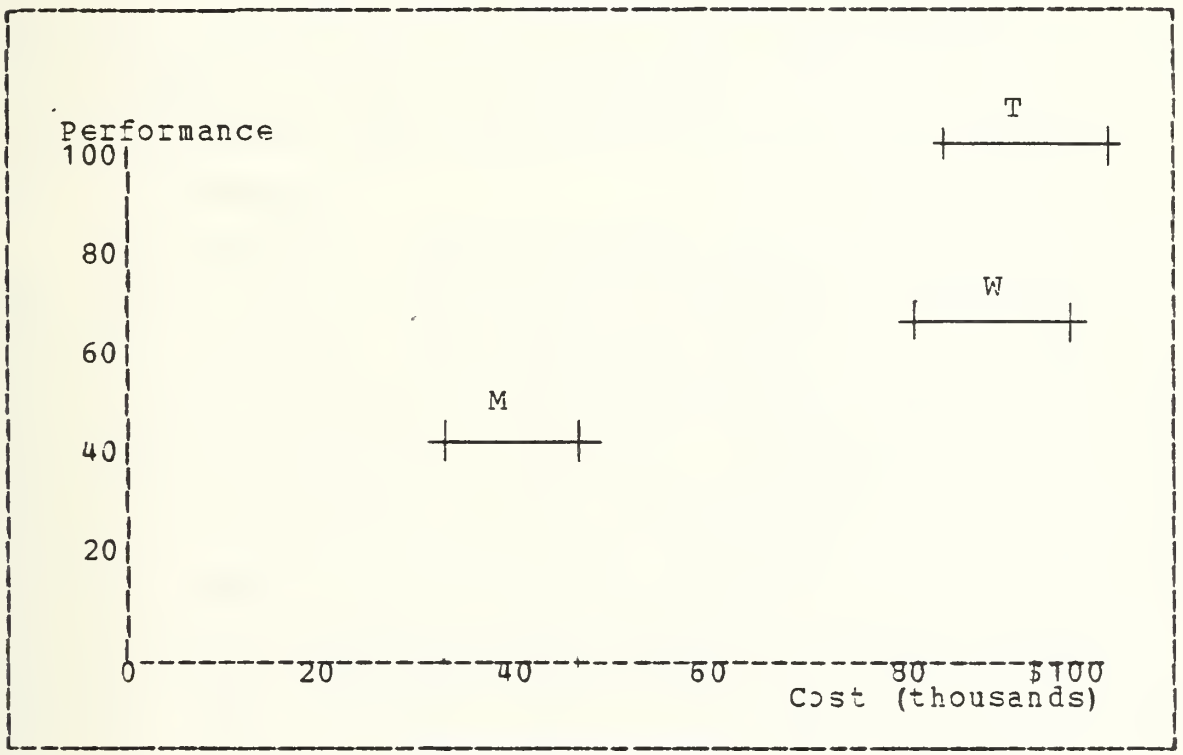

Figure 4.2 System Performance vs. System Cost Ranges.

allow for change in market hardware and software prices. Using a percentage of 10% to cover what the author considers

the most likely circumstance, a range is developed for the probable cost of each system:

1. $81,000 to $99,000 for the Qantel hardware and Trans-Pac software;
2. $78,900 to $96,500 for the Wang system and associated software;
3. $31,300 to $38,300 for the Intertec CompuStar network; and
4. $36,300 to $44,300 for the Nestar Cluster/One network.

These figures revise the original plot to that shown in Figure 4.2 . The highest and lowest microcomputer prices are used to bound the cost range of the Micro Networks alternative. Using this curve to figure the marginal costs between alternatives is slightly more difficult than before. Once ranges of numbers are addressed, the decision must be made as to from where within that range marginal changes will be measured.

To illustrate: The Wang system costs between $78,900 and $96,500 and the microcomputer alternative ranges from $31,300 to $44,300. The question is whether the change in cost should be computed between mid-points, between high and low figures separately, or between a combination of high and low figures. Whereas a given market responds as a single entity to influences on pricing, individual sellers need not react in unison. Any one of the manufacturers or vendors supplying the systems in this study may change its pricing policy without immediate and specific regard to the other vendors. Thus, if a ten percent price hike is experienced by the microcomputer alternative, it does not necessarily follow that the Wang system will undergo similar price changes. Furthermore, it may be argued that minicomputers and microcomputers are really separate markets; consequently pricing strategies in one do not influence the other. Since

there is no way to pre-determine the costs with certainty, the concept of risk aversion suggests calculating the marginal difference in cost using worst case figures, i.e., high and low prices. Thus, the highest marginal cost that the Wang system may incur is if the very cheapest price is paid for the microcomputer option while the higher price must be paid for Wang. Using worst case figures, the marginal cost for the Wang system is $96,500 minus $$31,300, or $65,200 for an increase of 22.5 performance points. The marginal cost between Trans-Pac and Wang is $99,000 minus $78,900, or $21,100 for an additional 38 performance points. The marginal cost of upgrading from the microcomputer option to Trans-Pac is $99,000 minus $31,300, or $67,700 for a 60.5 point increase. Under this analysis, the marginal cost figures are no longer as unfavorable to the Wang option as before price variation was addressed. While the $2,300 marginal cost previously calculated between Trans-Pac and Wang represented only three percent of the anticipated cost of the Wang system (i.e., an upgrade to Trans-Pac could be accomplished for 103% of Wang's price), this $21,100 worst case marginal cost represents almost 27% of the original Wang system price, making the upgrade decision one requiring some thought. The Micro Networks to Trans-Pac upgrade involves a 216% price augment for a 60.5% performance improvement.

Performance figures are also subject to change. The weighting formula applied above may not accurately reflect a specific user's valuation of the five software performance areas. For instance, another decision-maker reviewing these alternatives might value applications which perform calculations over those applications which primarily hold records and do not utilize the computing power of the computer, i.e., the concept of a "computerized filing cabinet." In that case, he might assign heavier weights to scheduling and

financial functions, which are mathematical, and less to maintenance, inventory and administrative record-keeping,

TABLE VI

Software Performance Variability A

	Trans-Pac	Wang	Micro Networks
Scheduling Support (40)	40	8	4
Equipment Maintenance (12)	12	11	2
Inventory Control (10)	10	8.5	7
Finance and Payroll (33)	33	26.5	25
Report Generation and File Maintenance (5)	5	3	3
Total	100	57	41

computerized activities which might be called "digital bookkeeping." This evaluation is shown in Table VI . The same point allocation percentages devised for Table V are used to determine the scores relative to the new weights.

The other subjective factor which affects the performance scores is the percentage of possible points allocated to each computer system once the weights have been established. The author's opinion of a software package's value to MST determined the scores attained under each weighting formula. Another decision-maker who believes that the user will learn to exploit the capabilities of a system would no doubt assign consistently higher values in each of the application areas. For example, an analyst may assume that a knowledgable user will, with practice, learn to extract more computational and decision-making power from the electronic spreadsheet and modeling application. This will

increase the system's value in the scheduling and planning area, for which the application was originally intended, and also increase the system's usefulness in the financial and administrative categories as the user utilizes the forecasting and statistical report generation capabilities. Such an evaluation, where the analyst assumes that the user will augment the ready-made abilities of the software with experience and perhaps his own programming, is shown in

TABLE VII

Software Performance Variability B

	Trans-Pac	Wang	Micro Networks
Scheduling Support (30)	30	21 (70%)	19.5 (65%)
Equipment Maintenance (25)	25	22.5 (90%)	16 (65%)
Inventory Control (12)	12	10 (85%)	8.5 (70%)
Finance and Payroll (18)	18	16 (90%)	16 (90%)
Report Generation and File Maintenance (15)	15	13.5 (90%)	13.5 (90%)
Total	100	83	73.5

Tables VII and VIII which apply revised allocation percentages to the two previously described weighting formulae.

Combining the two weighting formula and two point allocation percentages produces four software performance scores for each alternative, (although obviously, Trans-Pac did not vary from 100% performance as it is the standard). Taking the high and low scores for each yields a probable performance range for the competing systems:

1. 57 to 83 points for the Wang system; and
2. 39.5 to 73.5 points for the microcomputer networks.

TABLE VIII

Software Performance Variability C

	Trans-Pac	Wang	Micro Networks
Scheduling Support (40)	40	26	24
Equipment Maintenance (10)	10	9	6.5
Inventory Control (12)	12	10	8
Finance and Payroll (33)	33	29.5	29.5
Report Generation and File Maintenance (5)	5	4.5	4.5
Total	100	79	72.5

Figure 4.3 presents the revised cost-performance graph based upon the variability in both prices and performance levels.

Determination of the marginal costs between alternatives is made more difficult in this final cost-performance curve, as a range of performance is available for a range of prices. Once again, the policy of minimizing unknown risks indicates that the worst case instance should be used in the evaluation; that is, paying the most additional cost for the least amount of performance gain. The worst case cost factor, used in the preceeding analysis, is the higher price of the better-performing system, minus the cheapest price of the base system. The worst case performance factor is the opposite: the lowest performance level of the better system minus the best probable performance level of the lesser-performing system. The worst case marginal costs are shown below:

1. The marginal cost of obtaining the Wang system over the Micro Networks system is $65,200 for a possible decrease of 16.5 performance points;

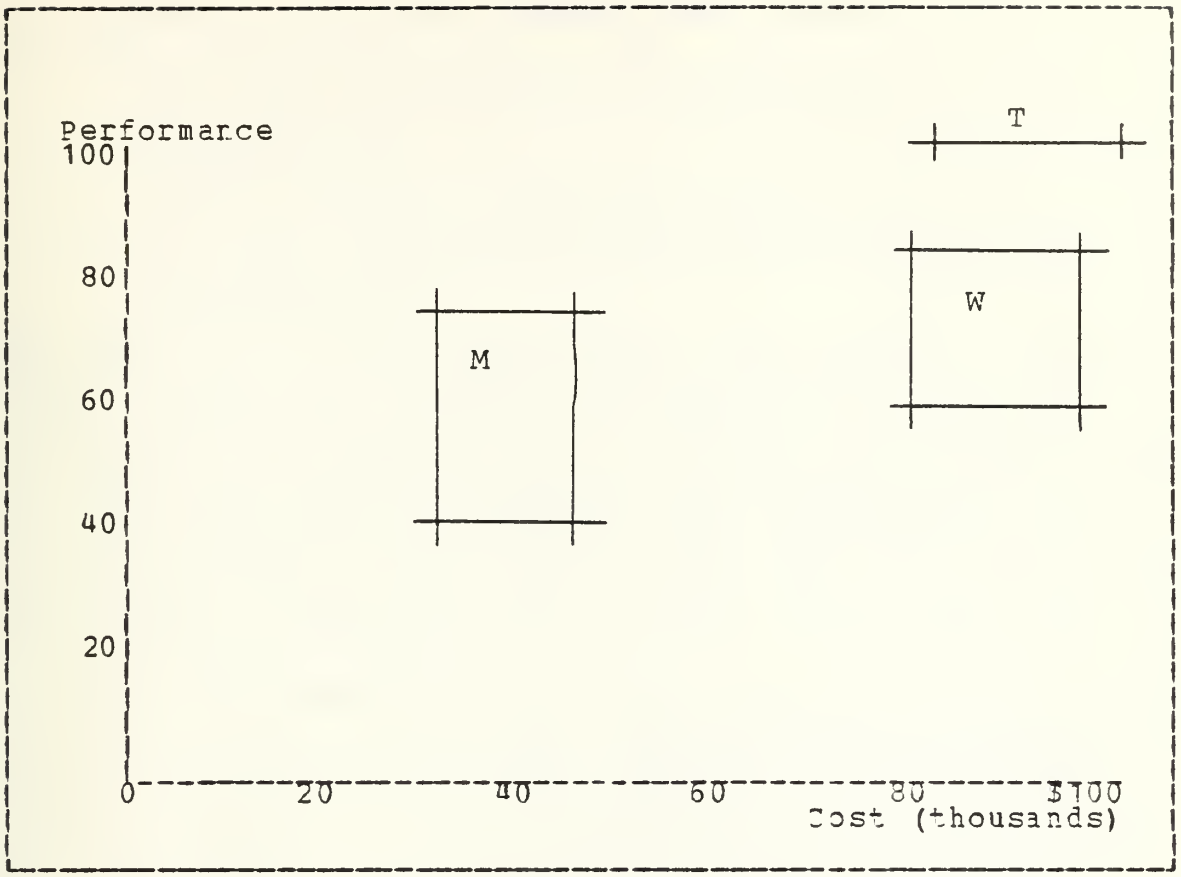

Figure 4.3 Performance Ranges vs. System Cost Ranges.

2. The marginal cost of obtaining the Trans-Pac system over the Wang system is $21,100 for an increase of 17 performance points; and
3. The marginal cost of obtaining Trans-Pac over the microcomputers is $67,700 for an increase of 26.5 performance points.

If, in fact, the decision-maker believed that the worst case circumstance would occur, i.e., that an upgrade from the Micro Networks to the Wang system would cost three times as much for 22% less performance, then the decision in favor of Wang would never be made. By using the midpoints of the three performance ranges as the expected performance levels,

the marginal performance obtained for the respective marginal costs is more competitive:

1. 13.5 additional points by choosing Wang over the microcomputer;
2. 30 more points by selecting Trans-Pac over Wang; and
3. 43.5 more points by choosing Trans-Pac over the microcomputer.

The instance of worst case marginal performance is improbable, because the analyst who optomistically views the potential of the software for one system would logically do the same for similar software on other systems (as illustrated in Tables VII and VIII). Thus, the point allocation percentages, though different for each alternative, tend to move up or down together.

Isolated changes in the scores can affect the relative position of the alternatives. Returning to the original scoring values, if only the evaluation of the scheduling support software is changed--increasing that capability by ten base points, for example--both the Wang and Micro Networks scores increase, narrowing the gap between them and Trans-Pac. Adding ten points, the Wang score is 72 and Micro Networks is 49.5. The marginal cost between those two alternatives does not change, remaining at $65,200 for 22.5 additional performance points, but the marginal cost between either alternative and Trans-Pac changes. The worst case marginal cost is still the same--$21,100 increase between Wang and Trans-Pac and $62,700 increase between Micro Networks and Wang--but the additional performance obtained for that price has dropped by ten to 28 points for Wang and 50.5 for the microcomputers, so that the extra money does not buy quite as much as before. Another scoring change, affecting only one alternative, affects the relative performance between all the options. If the Micro Networks alternative is given ten more points in the equipment

maintenance category, the resulting performance scores are 100 for Trans-Pac, 72 for Wang, and 59.5 for Micro Networks; and the marginal performance gain over the microcomputer alternative is 13.5 points for Wang and 40.5 points for Trans-Pac--still less performance for the money.

The preceding analysis has shown the sensitivity of the numbers to the individual perceptions of the analyst. The analysis can be done using so-called "expert" opinion to arrive at a set of total scores with which the decision-maker feels comfortable and confident. However, once the totals are finalized, only the responsible decision-maker can decide what trade-offs in cost and performance are acceptable. An observer can speculate that if the final totals produce marginal cost figures such that the Trans-Pac alternative provides 38% more performance at a 3% increase in price over the Wang system, as in the author's original evaluation, then the decision-maker would elect to spend the nominal increase for a substantial performance upgrade. But when the choice becomes less obvious, as when using the figures from Figure VIII where a 26% price increase created by choosing Trans-Pac over Wang yields a 21% performance increase, only the decision-maker who must live with and justify his decision should make the choice.

B. ADDITIONAL FACTORS

There are several important factors other than software performance which will influence the decision-maker's choice of computer system. These factors are not quantified in this thesis--nor are some subject to numerical analysis--but they are mentioned as areas which should be given consideration in the decision-making process.

Reliability of the system is of critical importance. Reliability refers not only to hardware reliability, but to software and data reliability. Processors are inherently reliable pieces of hardware because they are electical rather than mechanical. However, if the wirings or individual components of a minicomputer fail, all computing power is lost. Not so with a microcomputer network where a user confronted by a failed microcomputer simply moves to a working micro, recalls his files and continues. An adjunct to hardware reliability is its maintainability. Microcomputers have fewer components than minis due to single chip and single board technologies. The resultant modularity of design makes maintenance or replacement simple, quick and inexpensive.

Software reliability is, to a large extent, a function of whether a package is custom-tailored or of the off-the-shelf variety. Packaged software aimed at a wide market of users is highly reliable, requiring virtually no maintenance, except for user-desired modifications. Microcomputer software is often more exhaustively tested than software for individually-designed systems simply because of the economics of having to send revisions to hundreds of thousands of microcomputer users at no charge. Generally, after a few thousand copies of a program have been sold, all the bugs have been found.

The integrity of data is the key to any system, manual or automated. Computerized computations are unquestionably more accurate than manual calculations. Semiconductor memory is so reliable that many manufacturers dispense with parity checking.[8] Storage media are reliable too; a "Winchester" hard disk drive has a mean time to failure of

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[8]A parity bit is appended to the end of each data word and set odd or even to correspond to the odd or even value of the sum of the bits in the word. If the parity bit does not match the sum, an error is detected.

15,000 hours [15:30]. Data transmissions however, are susceptible to error. In Cluster/One, receiving nodes use check sums on the address and data of the packet. If the check sums don't match, the sender is signaled to retransmit its packet. Additionally, the file server locks a file if one user is accessing it so that concurrent changes cannot be made. Qantel's minicomputer does check parity bits but does not provide error correction if an error is found, nor does it provide storage protection to prevent unauthorized writing in certain areas of main memory, a feature used in timesharing and multiprogrammed memory schemes. Wang 2200 MVP does not offer any of the three features. CompuStar provides neither error checking or correction. Storage protection is not needed in systems which dedicate memory to one process.

There are many other considerations in choosing a system. Physical site preparation, if needed is an additional cost. The larger the machine, the greater the need for a controlled environment. A large machine will require more power and radiate more heat, thus demanding artificial cooling. A microcomputer needs no special environment, nor do most small minicomputers. The support that a buyer gets from the vendor is often a major selling point. Some users, especially computer-naive ones, desire much attention or "hand-holding" in the jargon. Such personal attention may incurr additional fees or it may be part of the vendor's way of doing business. Unfortunately, the computer industry is a volatile one and the vendor who sold you a system yesterday might not be around tomorrow. A company's reputation is an important element to check before signing a contract.

C. CONCLUSIONS

This study has focused on one company in particular to illustrate the process of requirements analysis and capacity planning. First, the current system was analyzed to determine what information was being maintained and how it flowed through the company. The filing system was examined to allow specification of application areas to be addressed by an automated system, and to facilitate proper sizing of the system in terms of storage and data entry equipment. Once the requirements were defined, four systems were presented to meet those requirements, two minicomputer systems and two multi-user microcomputer systems. Costs of hardware and software were drawn from various sources to arrive at a total cost for each system. These costs are subject to change, due to both the variability of the marketplace and the general nature of the compilation. To give meaning to the costs, measures of performance were established using two weighted evaluation schemes and several point allocations within the weighting formulae. The resultant graph compared the four systems in terms of performance ranges and cost ranges. The derivation of the marginal cost associated with each change in levels of performance enables a decision-maker, who knows his subjective value of an increment of performance, to determine which alternative is "best" for him. If the cost of the increment outweighs his subjective valuation of that increment, he does not spend the extra money for it; whereas a cost less than his value of the performance increment asserts that the extra money should be spent. This thesis presents the computer system options in an evaluated and quantified form, so that the decision-maker may apply his subjective value of performance and money to determine which alternative best meets his needs.

TABLE IX

Personnel and Payroll Files

File name	Description	Input from	Input to	No. of records
Personnel	name, address, tax status, dependents, career history,	individual	personnel and payroll	100
Equal Employment Opportunity	employee sex, race, age, religin	individual	EEO report	100
Driver Perforance	performance evaluations, accident/incident involvement	accident and safety file, management	personnel	70
Training	mandatory and voluntary training sessions attended by mechanics, coach operations, and clerics	maintenance & operations supervisors	personnel	95
Attendance	seven categories of time per day per driver (e.g, training, duty, leave)	dispatcher	Sec. 15 reports	70
Operator Timekeeping	time card compares actual time to scheduled time; maintains 21 categories of duty time	dispatcher & planner (schedules)	payroll Sec. 15 reports	70
Payroll	wage,hours,withholding	personnel	G/L	100

TABLE X

Maintenance Files and Reports

File name	Description	Input from	Input to	No. of records
Daily Fuel Report	fuel, oil, and automatic transmission fluid consumption (ATF) daily by vehicle	vehicle	fuel and oil ledger and vehicle report	50 daily
Fuel and Oil Ledger	consolidated fuel, oil, and ATF consumption	daily fuel report	monthly maintenance report	50 daily
Vehicle Fuel and Oil 5	fuel, oil, and ATF consumption by vehicle number	daily fuel report	vehicle history	50
Equipment Assignment Sheet	list of operative and inoperative vehicles for scheduling purposes	maintenance and planner	dispatcher	1 daily
Tire History	location of and mileage on each leased tire (all are leased)	maintenance	tire lessor	365
Brake History	brake jobs by vehicle number	maintenance	vehicle history	50
Vehicle History	Work orders, repair history, overhauls, hubodometer changes for each vehicle	maintenance	maintenance	50
Preventive Maintenance Report	weekly status on PM by vehicle for last and next scheduled maintenance	maintenance	management	1 per week
Monthly Maintenance Report	mileage (revenue-producing and total), fuel, oil, ATF consumption and inventory activity	maintenance	management and planner	1 per month
Vendor List	vendors by parts supplied, price, comments	maintenance	purchase order	275
Inventory	part name, number, quantity, location (Mtry/Slns, shelf) cost, vendor	maintenance	maintenance and management	1 per year

TABLE XI

Financial Files

File name	Description	Input from	Input to	No. of records
General Ledger	standard chart of accounts: monthly & year-to-date actual budgeted expenses and revenues, assets and liabilities	financial subsystems (A/P, fixed assets, A/R)	balance sheet	225
Accounts Payable	vendor, address, part cost, date, discount	purchase order	cash distr. journal	120 /mo
Accounts Receivable	name,address,charge, description, date: for charters	controller	invoices	30 /yr
Fixed Assets	account number, desription, item life monthly & cumulative depreciation	controller	finance reports, G/L	700

TABLE XII

Service Planning and Scheduling Files

File name	Description	Input from	Input to	No. of records
Ridership survey	vehicle no.,method of payment, for each stop: passengers on/off/onboard distance/minutes between stops, passengers per minute, per mile	survey	routes & runs scheduling, service planning	1000
Schedule Timetable	time on/off duty, when/ where to break, total guaranteed & overtime for each coach run	plans	trans payroll	35
Routes	route characteristics: traffic signals, railroad crossings,street widths,route length	external	run-cutting	27
Vehicle Info	condition, size capacity	maintenance	run-cutting	52
Runs	no. of drivers, routes, vehicle info	routes	schedule	55

TABLE XIII

Reports and Efficiency Measures

File name	Description	Input from	Input to
Efficiency Measures	passenger and revenue mile, total passengers per revenue mile and service hour, service hours per employee	controller	external reporting
Service Delays	late trips, reason, month	dispatcher	management
Road Calls	date, vehicle no., assistance (mechanical or not), miles between road calls	dispatcher planner, maintenance	management
Charters	date, vehicle, route, charge	controller	controller
Five Year Plan	proposed projects, operating and capital improvements	management, all depts.	Board
Performance Statistics	operating costs (ops, maint, admin) farebox revenues, total passengers, revenue miles, service hours, total roadcalls, accidents	maintenance, controller, dispatch log accident/ safety file	management Board

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